

## SPECIFICATION

## THERAPEUTIC AGENT FOR NEURODEGENERATIVE DISORDERS

Field of the Invention

5           The present invention relates to a therapeutic agent for neurodegenerative disorders.

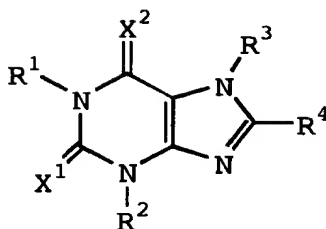
Background of the Invention

10           Most of the compounds according to the present invention are known compounds, and their adenosine A<sub>2</sub>-receptor antagonism, anti-Parkinson's disease action, anti-depressive action, anti-asthmatic action, inhibitory action on bone absorption and action on central excitation are known [Japanese Published Examined Patent Application No. 26516/72, J. Med. Chem., 34, 1431 (1991), J. Med. Chem., 36, 1333 (1993), WO 92/06976, 15 Japanese Published Unexamined Patent Application No. 211856/94, Japanese Published Unexamined Patent Application No. 239862/94, WO 95/23165, Japanese Published Unexamined Patent Application No. 16559/94 and WO 94/01114).

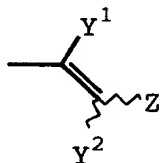
20           However, it is not known that said compounds have an inhibitory action on neurodegeneration.

Disclosure of the Invention

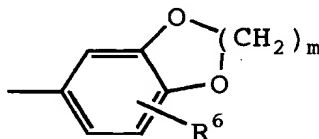
          The present invention relates to a therapeutic agent for neurodegenerative disorders, comprising, as an active ingredient, xanthine derivatives represented by formula (I):



wherein  $R^1$ ,  $R^2$  and  $R^3$  independently represent hydrogen, lower alkyl, lower alkenyl or lower alkynyl;  $R^4$  represents cycloalkyl,  $-(CH_2)_n-R^5$  (wherein  $R^5$  represents substituted or unsubstituted aryl, or a substituted or unsubstituted heterocyclic group, and  $n$  is an integer of 0 to 4), or the following group:



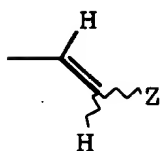
wherein  $Y^1$  and  $Y^2$  independently represent hydrogen, halogen or lower alkyl, and  $Z$  represents substituted or unsubstituted aryl, the following group:



wherein  $R^6$  represents hydrogen, hydroxy, lower alkyl, lower alkoxy, halogen, nitro or amino, and  $m$  is an integer of 1 to 3, or a substituted or unsubstituted heterocyclic group; and  $X^1$  and  $X^2$  independently represent O or S, or pharmaceutically acceptable salts thereof.

As the active ingredient for the therapeutic agent for neurodegenerative disorders, preferred compounds are compounds of formula (I) wherein  $X^1$  and  $X^2$  are O, or pharmaceutically acceptable salts thereof; or compounds of

formula (I) wherein R<sup>4</sup> is the following group:



wherein Z has the same meaning as defined above, or pharmaceutically acceptable salts thereof, and specifically preferred compounds are compounds of formula (I) wherein X<sup>1</sup> and X<sup>2</sup> are O and R<sup>4</sup> is the group defined above, or pharmaceutically acceptable salts thereof.

Further, the present invention relates to a method of treating neurodegenerative disorders, which comprises administering an effective dose of a xanthine derivative represented by formula (I) or a pharmaceutically acceptable salt thereof.

Furthermore, the present invention relates to use of a xanthine derivative represented by formula (I) or a pharmaceutically acceptable salt thereof for manufacturing a pharmaceutical composition useful for treatment of neurodegenerative disorders.

Hereinafter, the compound represented by formula (I) is referred to as compound (I).

In the definition of compound (I), the lower alkyl and the lower alkyl moiety in the lower alkoxy mean a straight-chain or branched C<sub>1</sub> to C<sub>6</sub> alkyl group such as methyl, ethyl, propyl, isopropyl, butyl, isobutyl, sec-butyl, tert-butyl, pentyl, neopentyl and hexyl; the lower alkenyl means a straight-chain or branched C<sub>2</sub> to C<sub>6</sub> alkenyl group such as vinyl, allyl, methacryl,

crotyl, 3-butenyl, 2-pentenyl, 4-pentenyl, 2-hexenyl and  
5-hexenyl; the lower alkynyl means a straight-chain or branched  
C<sub>2</sub> to C<sub>6</sub> alkynyl group such as ethynyl, propargyl, 2-butyne,  
3-butyne, 2-pentyne, 4-pentyne, 2-hexyne, 5-hexyne and  
5 4-methyl-2-pentyne; the aryl means phenyl or naphthyl; the  
cycloalkyl means a C<sub>3</sub> to C<sub>8</sub> cycloalkyl group such as cyclopropyl,  
cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl and  
cyclooctyl; examples of the heterocyclic groups are furyl,  
thienyl, pyrrolyl, pyranyl, thiopyranyl, pyridyl, thiazolyl,  
10 imidazolyl, pyrimidyl, triazinyl, indolyl, quinolyl, purinyl  
and benzothiazolyl; and the halogen includes fluorine, chlorine,  
bromine and iodine. The substituted aryl and the substituted  
heterocyclic group have 1 to 3 independently-selected  
substituents such as lower alkyl, hydroxy, substituted or  
15 unsubstituted lower alkoxy, halogen, nitro, amino, lower  
alkylamino, di(lower alkyl)amino, trifluoromethyl, tri-  
fluoromethoxy, benzyloxy, phenyl, phenoxy, lower alkanoyl,  
lower alkanoyloxy, aroyloxy, aralkanoyloxy, carboxy, lower  
alkoxycarbonyl, lower alkylcarbamoyl, di(lower alkyl)-  
20 carbamoyl, sulfo, lower alkoxysulfonyl, lower alkylsulfamoyl  
and di(lower alkyl)sulfamoyl. The lower alkyl and the alkyl  
moiety of the lower alkoxy, lower alkylamino, di(lower  
alkyl)amino, lower alkanoyl, lower alkanoyloxy, lower  
alkoxycarbonyl, lower alkylcarbamoyl, di(lower alkyl)-  
25 carbamoyl, lower alkoxysulfonyl, lower alkylsulfamoyl and  
di(lower alkyl)sulfamoyl have the same meaning as the lower  
alkyl defined above. The halogen has the same meaning as the

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halogen defined above. Examples of the substituents for the substituted lower alkoxy are hydroxy, lower alkoxy, halogen, amino, azido, carboxy and lower alkoxycarbonyl. The alkyl moiety of the lower alkoxy and lower alkoxycarbonyl has the same meaning as the lower alkyl defined above, and the halogen has the same meaning as the halogen defined above. The aroyl moiety of the aroyloxy includes benzoyl and naphthoyl. The aralkyl moiety of the aralkanoyloxy includes benzyl and phenethyl.

10 The pharmaceutically acceptable salts of compound (I) include pharmaceutically acceptable acid addition salts, metal salts, ammonium salts, organic amine addition salts and amino acid addition salts.

15 The pharmaceutically acceptable acid addition salts of compound (I) include inorganic acid addition salts such as hydrochloride, sulfate and phosphate, and organic acid addition salts such as acetate, maleate, fumarate, tartrate, citrate and methanesulfonate; the pharmaceutically acceptable metal salts include alkali metal salts such as sodium salt and 20 potassium salt, alkaline earth metal salts such as magnesium salt and calcium salt, aluminum salt, and zinc salt; the pharmaceutically acceptable ammonium salts include ammonium and tetramethylammonium; the pharmaceutically acceptable organic amine addition salts include salts with morpholine and 25 piperidine; and the pharmaceutically acceptable amino acid addition salts include salts with lysine, glycine and phenylalanine.

Compound (I) including a novel compound can be produced by the methods disclosed in the above-mentioned publications or according to the methods. The desired compound in the process can be isolated and purified by purification methods  
5 conventionally used in synthetic organic chemistry, such as filtration, extraction, washing, drying, concentration, recrystallization and various kinds of chromatography.

In the case where a salt of compound (I) is desired and it is produced in the form of a desired salt, it may be subjected  
10 to purification as such. In the case where compound (I) is produced in the free form and its salt is desired, it is dissolved or suspended in a suitable solvent, and then an acid or a base may be added thereto to form the salt.

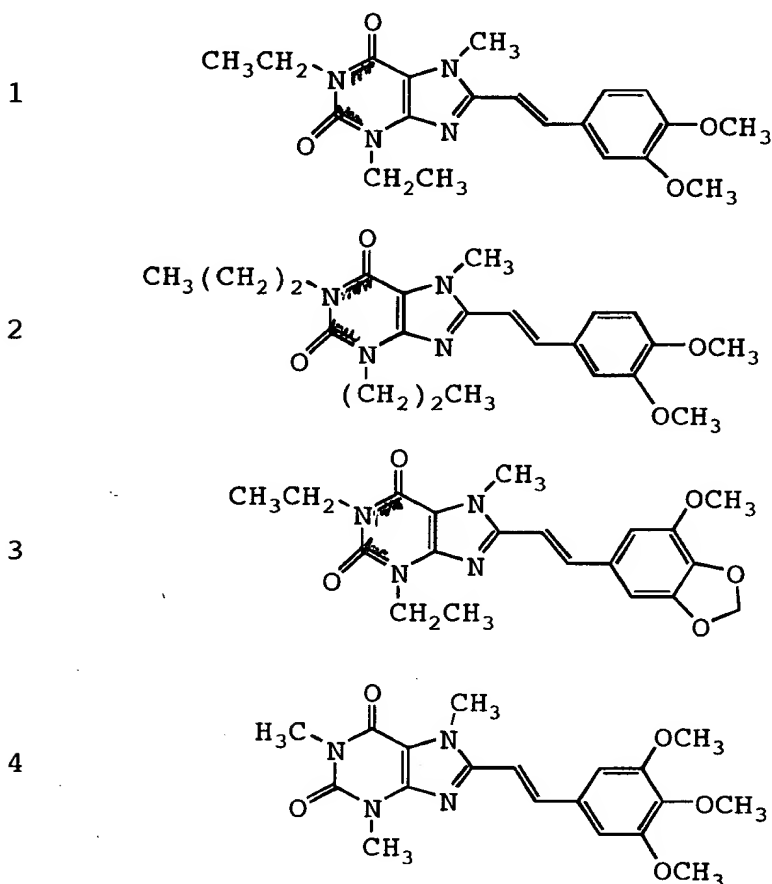
Compound (I) and pharmaceutically acceptable salts  
15 thereof may be in the form of adducts with water or various solvents, which can satisfactorily be used as the therapeutic agent of the present invention.

Some of compounds (I) have optical isomers, and all potential stereoisomers and mixtures thereof can  
20 satisfactorily be used as the therapeutic agent of the present invention.

Examples of compound (I) are shown in Table 1.

Table 1

Compound No.



Compound 1: (E)-1,3-diethyl-8-(3,4-dimethoxystyryl)-7-methylxanthine (Japanese Published Unexamined Patent

5 Application No. 211856/94)

Melting point: 190.4-191.3 °C

Elemental analysis: C<sub>20</sub>H<sub>24</sub>N<sub>4</sub>O<sub>4</sub>

Calcd. (%): C 62.48, H 6.29, N 14.57

Found (%): C 62.52, H 6.53, N 14.56

10 IR(KBr)  $\nu_{\max}$ (cm<sup>-1</sup>): 1697, 1655, 1518

NMR(CDCl<sub>3</sub>, 270MHz)  $\delta$ (ppm): 7.74(1H, d, J=15.5Hz), 7.18(1H, dd,

J=8.3, 1.9Hz), 7.08(1H, d, J=1.9Hz), 6.89(1H, d, J=8.3Hz), 6.77(1H, d, J=15.5Hz), 4.21(2H, q, J=6.9Hz), 4.09(2H, q, J=6.9Hz), 4.06(3H, s), 3.96(3H, s), 3.93(3H, s), 1.39(3H, t, J=6.9Hz), 1.27(3H, t, J=6.9Hz)

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Compound 2: (E)-8-(3,4-dimethoxystyryl)-1,3-dipropyl-7-methylxanthine (WO 92/06976)

Melting point: 164.8-166.2 °C (Recrystallization from 2-propanol/water)

10 Elemental analysis: C<sub>22</sub>H<sub>28</sub>N<sub>4</sub>O<sub>4</sub>

Calcd. (%): C 64.06, H 6.84, N 13.58

Found (%): C 64.06, H 6.82, N 13.80

IR(KBr)  $\nu_{\max}(\text{cm}^{-1})$ : 1692, 1657

15 NMR(DMSO-d<sub>6</sub>, 270MHz)  $\delta(\text{ppm})$ : 7.60(1H, d, J=15.8Hz), 7.04(1H, d, J=2.0Hz), 7.28(1H, dd, J=2.0, 8.4Hz), 7.18(1H, d, J=15.8Hz), 6.99(1H, d, J=8.4Hz), 4.02(3H, s), 3.99(2H, t), 3.90-3.80(2H, m), 3.85(3H, s), 3.80(3H, s), 1.85-1.50(4H, m), 1.00-0.85(6H, m)

20 Compound 3: (E)-1,3-diethyl-8-(3-methoxy-4,5-methylenedioxy styryl)-7-methylxanthine (Japanese Published Unexamined Patent Application No. 211856/94)

Melting point: 201.5-202.3 °C

Elemental analysis: C<sub>20</sub>H<sub>22</sub>N<sub>4</sub>O<sub>5</sub>

25 Calcd. (%): C 60.29, H 5.57, N 14.06

Found (%): C 60.18, H 5.72, N 13.98

IR(KBr)  $\nu_{\max}(\text{cm}^{-1})$ : 1694, 1650, 1543, 1512, 1433

NMR(DMSO-d<sub>6</sub>, 270MHz) δ(ppm): 7.58(1H, d, J=15.8Hz), 7.23(1H, d, J=15.8Hz), 7.20(1H, d, J=1.0Hz), 7.09(1H, d, J=1.0Hz), 6.05(2H, s), 4.09-4.02(2H, m), 4.02(3H, s), 3.94-3.89(2H, m), 3.89(3H, s), 1.25(3H, t, J=7.2Hz), 1.13(3H, t, J=6.9Hz)

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Compound 4: (E)-8-(3,4,5-trimethoxystyryl)caffeine (Japanese Published Examined Patent Application No. 26516/72)

IR(KBr) v<sub>max</sub>(cm<sup>-1</sup>): 1702, 1667, 1508, 1432

10 NMR(DMSO-d<sub>6</sub>, 270MHz) δ(ppm): 7.61(1H, d, J=16.0Hz), 7.25(1H, d, J=16.0Hz), 7.09(2H, s), 4.03(3H, s), 3.85(6H, s), 3.71(3H, s), 3.45(3H, s), 3.21(3H, s)

MS(EI) 386(M<sup>+</sup>)

15 Hereinafter, the pharmacological activity of compound (I) is shown by the following Test Examples.

#### Test Example 1: Inhibitory Action on Neurodegeneration

The experiment was conducted according to the method of Sundstrom et al. (Brain. Res. Bulletin, 21, 257-263 (1988)).

20 In the experiment, 9- to 10-week-old male C57BL/6NCrj mice (supplied by Nippon Charles River) were used. During the period of preliminary breeding, the animals were kept in a laboratory at room temperature (22 to 24 °C) under 50 to 60 % humidity and allowed food and water ad libitum.

25 1-Methyl-4-phenyl-1,2,3,6-tetrahydropyridine hydrochloride (abbreviated hereinafter as MPTP HCl (RBI Co., Ltd.)) was dissolved at a concentration of 4 mg/ml in physiological saline. A test compound was suspended at a

concentration of 1 mg/ml in 0.3 % dimethyl sulfoxide (DMSO). Each test group consisted of 9 to 10 animals, and a control group was intraperitoneally given physiological saline, and an MPTP HCl administration group and an MPTP HCl + test compound administration group were intraperitoneally given MPTP HCl (40 mg/kg).

After 1 hour, the control group and the MPTP HCl administration group were orally given 0.3 % Tween, and the MPTP HCl + test compound administration group was orally given the test compound (10 mg/kg). After 1 week, the animals were decapitated, and the striatum was removed therefrom under cooling on ice. The striatum was stored in a deep freezer (< -80°C) before a binding experiment.

A [3H]-mazindol binding test was conducted in the following method. A striatum and 300 µl of buffer (120 mM NaCl, 5 mM KCl, 50 mM Tris, pH 7.9) were put into a micro-centrifuge tube and homogenized by portable homogenizer S-203 (manufactured by <sup>Tuehi</sup>~~Ikeda-Rika~~) and centrifuged at 15,000 rpm, 4°C for 5 minutes (by KUBOTA 1710). The precipitates were suspended in 300 µl of buffer and then centrifuged again at 15,000 rpm, 4°C for 5 minutes. The precipitates were suspended in 500 µl of buffer and then distributed into four test tubes in 100 µl portions. The remaining suspension (100 µl) was used for protein quantification. To determine non-specific binding, nomifensine maleate (RBI Co., Ltd.) (final concentration: 10 µM) as an inhibitor of dopamine uptake was added to two test tubes among the four test tubes. The binding reaction was

initiated by adding 25  $\mu$ l of [ $^3$ H]-mazindol (final concentration: 10 nM) (Spec. Act. 888 GBq/mmol, a product of NET). The mixture was incubated for 1 hour under cooling on ice, and the striatum homogenate was adsorbed onto a glass filter (Whatman, GF/B) in a cell harvester and washed three times with 5 ml of buffer. The radioactivity on the glass filter was measured with a liquid scintillation counter. For each striatum, specific [ $^3$ H]-mazindol binding was determined by subtracting the average of non-specific [ $^3$ H]-mazindol binding from the average of total [ $^3$ H]-mazindol binding.

Protein quantification was conducted by use of a Bio-Rad DC protein assay kit (Bio-Rad Co., Ltd.) with bovine serum albumin (Sigma Co., Ltd.) as a standard. Specific [ $^3$ H]-mazindol binding was expressed as the amount of bound [ $^3$ H]-mazindol per unit weight of protein, and the mean  $\pm$  standard error was determined for each group (<sup>9-10</sup>~~10~~ animals).

In Table 2, the results are expressed in terms of the amount of specifically bound [ $^3$ H]-mazindol (fmol/mg protein) in the striatum.

Table 2

Test groups	
Control	1140.3 $\pm$ 50.0
MPTP HCl	616.3 $\pm$ 32.8###
MPTP HCl + compound 1	950.9 $\pm$ 54.1***
Control	1219.3 $\pm$ 66.4
MPTP HCl	621.2 $\pm$ 27.7###
MPTP HCl + compound 2	784.8 $\pm$ 41.6**
MPTP HCl + compound 3	794.9 $\pm$ 28.5**
Control	1214.8 $\pm$ 46.2
MPTP HCl	674.2 $\pm$ 38.1###
MPTP HCl + compound 4	923.5 $\pm$ 51.1**

\*\* : p < 0.01 (compared with the group given MPTP HCl alone).

\*\*\* : p < 0.001 (compared with the group given MPTP HCl alone).

### : p < 0.001 (compared with the control group).

(n = 9 to 10; Wilcoxon rank sum test)

According to the test results, the reduction of the amount of specifically bound [<sup>3</sup>H]-mazindol by administration of MPTP HCl was inhibited by compound 1. That is, it was revealed that compound 1 exhibits inhibitory action on degeneration of dopaminergic neurons.

#### Test Example 2: Acute Toxicity Test

Test compounds were orally or intraperitoneally administered to groups of ~~dd-strain~~ <sup>dd-strain</sup> male mice weighing 20  $\pm$  1 g, each group consisting of three mice. Seven days after the administration, the mortality was observed to determine a minimum lethal dose (MLD) of each compound.

The MLD value of Compound 1 was greater than 1000 mg/kg for oral administration.

Compound (I) or pharmaceutically acceptable salts thereof have inhibitory action on neurodegeneration and are

useful as a therapeutic agent for neurodegenerative disorders  
such as Alzheimer's disease, progressive supranuclear palsy,  
AIDS brain fever, propagating spongy brain fever, Huntington's  
chorea, multiple sclerosis, amyotrophic lateral sclerosis  
5 (ALS), multi-system atrophy, brain ischemia, and attention  
deficit hyperactivity disorder.

Compound (I) or pharmaceutically acceptable salts  
thereof can be used as such or in the form of various  
pharmaceutical compositions. The pharmaceutical  
10 compositions of the present invention can be prepared by  
uniformly mixing an effective amount of compound (I) or a  
pharmaceutically acceptable salt thereof as an active  
ingredient with pharmaceutically acceptable carriers. The  
pharmaceutical compositions are preferably in a unit dosage  
15 form suitable for rectal administration, oral or parenteral  
(including subcutaneous, intravenous and intramuscular  
administration) administration, etc.

For preparing a pharmaceutical composition for oral  
administration, any useful pharmaceutically acceptable  
20 carriers can be used. For example, liquid preparations for  
oral administration such as suspension and syrup can be prepared  
using water; sugars such as sucrose, sorbitol and fructose;  
glycols such as polyethylene glycol and propylene glycol; oils  
such as sesame oil, olive oil and soybean oil; preservatives  
25 such as a p-hydroxybenzoate; flavors such as strawberry flavor  
and peppermint, etc. Powder, pills, capsules and tablets can  
be prepared using excipients such as lactose, glucose, sucrose

and mannitol; disintegrating agents such as starch and sodium alginate; lubricants such as magnesium stearate and talc; binders such as polyvinyl alcohol, hydroxypropyl cellulose and gelatin; surfactants such as fatty acid esters; plasticizers such as glycerin, etc. Tablets and capsules are the most useful oral unit dosage because of the readiness of administration. For preparing tablets and capsules, solid pharmaceutical carriers are used.

Injectable preparations can be prepared using carriers such as distilled water, a salt solution, a glucose solution and a mixture of a salt solution and a glucose solution. The preparation can be prepared in the form of solution, suspension or dispersion according to a conventional method by using a suitable auxiliary.

Compound (I) or a pharmaceutically acceptable salt thereof can be administered orally in the pharmaceutical form described above or parenterally as the injection. The effective dose and administration schedule vary depending on the mode of administration, age, weight, and symptoms of a patient, etc. However, generally, compound (I) or a pharmaceutically acceptable salt thereof is administered in a dose of 1 to 900 mg/60 kg/day, preferably in a dose of 1 to 200 mg/60 kg/day.

Certain embodiments of the present invention are described in the following examples.

#### EXAMPLE

### Example 1: Tablets

Tablets having the following composition were prepared in a conventional manner.

Compound 1 (40 g) was mixed with 286.8 g of lactose and 60 g of potato starch, followed by addition of 120 g of a 10% aqueous solution of hydroxypropyl cellulose. The resultant mixture was kneaded, granulated, and then dried by a conventional method. The granules were refined to give granules used to make tablets. After mixing the granules with 1.2 g of magnesium stearate, the mixture was formed into tablets each containing 20 mg of the active ingredient by using a tablet maker (Model RT-15, Kikusui) having pestles of 8 mm diameter.

The prescription is shown in Table 3.

Table 3

Compound 1	20	mg
Lactose	143.4	mg
Potato Starch	30	mg
Hydroxypropyl Cellulose	6	mg
Magnesium Stearate	0.6	mg
	200	mg

### Example 2: Capsules

Capsules having the following composition were prepared in a conventional manner.

Compound 1 (200 g) was mixed with 995 g of Avicel and 5 g of magnesium stearate. The mixture was put in hard capsules

No. 4 each having a capacity of 120 mg by using a capsule filler (Model LZ-64, Zanashi) to give capsules each containing 20 mg of the active ingredient.

The prescription is shown in Table 4.

5

Table 4

Compound 1	20 mg
Avicel	99.5 mg
Magnesium Stearate	0.5 mg

10

120 mg

#### Example 3: Injections

Injections having the following composition were prepared in a conventional manner.

15

Compound 1 (1 g) was dissolved in 100 g of purified soybean oil, followed by addition of 12 g of purified egg yolk lecithin and 25 g of glycerin for injection. The resultant mixture was made up to 1,000 ml with distilled water for injection, thoroughly mixed, and emulsified by a conventional method. The resultant dispersion was subjected to aseptic filtration by using 0.2  $\mu$ m disposable membrane filters, and then aseptically put into glass vials in 2 ml portions to give injections containing 2 mg of the active ingredient per vial.

20

The prescription is shown in Table 5.

25

Table 5

	Compound 1	2	mg
	Purified Soybean Oil	200	mg
	Purified Egg Yolk Lecithin	24	mg
5	Glycerine for Injection	50	mg
	Distilled Water for Injection	1.72	ml
		2.00	ml

## Example 4: Anal suppository

10 Formulations for rectal administration having the following composition were prepared in a conventional manner.

Witepsol® H15 (678.8 g, manufactured by Dynamit Nobel, Ltd.) and Witepsol® E75 (290.9 g, manufactured by Dynamit Nobel, Ltd.) were melted at 40 to 50 °C. In the resulting molten mixture  
 15 were uniformly mixed and dispersed Compound 1 (2.5 g), potassium dihydrogen phosphate (13.6 g) and disodium hydrogen phosphate (14.2 g). The resulting dispersion was poured into plastic suppository molds, and gradually cooled to give anal suppositories containing 2.5 mg of the active ingredient per  
 20 formulation.

The prescription is shown in Table 6.

Table 6

	Compound 1	2.5 mg
	Witepzol H15	678.8 mg
	Witepzol E75	290.9 mg
5	Potassium dihydrogen phosphate	13.6 mg
	Disodium hydrogen phosphate	14.2 mg
		<hr/>
		1000. mg

Industrial Applicability

10        The present invention provides a therapeutic agent for neurodegenerative disorders, comprising a xanthine derivative or a pharmaceutically acceptable salt thereof as an active ingredient.